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THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

A STUDY OF THE EFFECT OF FIBER AND PROCESS VARIABLES ON THE MECHANICAL PROPERTIES OF THE COMPONENTS OF COMBINED BOARD

PART II. EFFECT OF BASIS WEIGHT, DEGREE OF REFINING AND BEATER ADDITIVES ON THE PROPERTIES OF KRAFT HANDSHEETS OF COMMERCIAL WEIGHTS

√ Project 1108-4

A Preliminary Report

to the

Technical Committee

Fourdrinier Kraft Board Institute, Inc.

September 15, 1964

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Earlier studies were concerned with the effect of basis weight and degree of refining of kraft handsheets with respect to those properties which are of primary importance to top-to-bottom compression strength. The present study extends the work to handsheets which are of commercially significant basis weight. In addition the effects of two beater additives (guar and polyethyleneimine) were studied.

The scope of the study was as follows: three-ply (wet-laminated) handsheets were made up in five basis weights (33, 42, 51, 69, and 90-lb./1000 sq. ft.) at three freeness levels (700, 600 and 500 cc.); 42-lb. sheets were made also at 400 and 300 cc. freeness. Single-ply sheets were formed in the 42-lb. weight at 600 cc. to enable comparison of single- and multi-ply sheets. Additional 42-lb. sheets were formed at 600 cc. with varying percentages of guar and polyethyleneimine (0.25, 0.75 and 1.25% by weight) to determine the effect of these beater additives on the strength properties of interest. The following properties were evaluated:

Basis weight

Caliper, t

Density

Modified ring compression

Extensional stiffness, Et

Modulus of elasticity, E

Taber stiffness

Z-direction tensile strength

Instron tensile strength and stretch

The above named test properties are shown in Table I for each experimental condition. The effects of basis weight and degree of refining are shown graphically in Figures 1 to 8 and 10 to 12. The curves in these figures were fitted visually. Among the conclusions which may be drawn from these data are the following:

1. Modified ring compression, extensional stiffness and caliper are approximately proportional to basis weight at a given degree of refining.

2. Modulus of elasticity is sensibly independent of basis weight.

3. Taber stiffness increases non-linearly with basis weight, mainly because stiffness depends on the cube of the caliper.

4. An increase in degree of refining in the range of 700 to 500 cc. freeness increased modified ring compression, extensional stiffness, modulus of elasticity, and Z-direction tensile strength. Taber stiffness decreased with increased refining because of reduction in thickness.

5. In general, the properties of the single-ply handsheets were at about the same level as the corresponding three-ply sheets. A notable exception was the higher Z-direction tensile strength of the single-ply sheets, which appears to be reflected in the slightly higher modified ring compression strength.

Several interrelationships between the abovementioned mechanical properties are shown graphically in Figures 9 and 13 to 15.

The effects of guar and polyethyleneimine (PEI) additives on the strength and stiffness properties of the handsheets are shown in Table II. The maximum improvement in modified ring compression was achieved with 0.75% concentration for both additives, giving 17% increase in edgewise compression in the case of PEI and 10% with guar. Modulus of elasticity and extensional stiffness were increased only modestly by these additives. Bonding was markedly improved by PEI, as evidenced by increases of as much as 75% in Z-direction tensile strength.

TABLE I

PHYSICAL PROPERTIES OF HANDSHEETS

Freeness, cc.	Beater Type	Additive %	Basis Weight, lb./1000 ft.²	Thickness, t, pts.	Apparent Density,[b] Units	Modified Ring Compression, lb./in.	Extensional Stiffness, Et, lb./in.	Modulus of Elasticity, E, lb./sq. in.	Tensile Strength, lb./in.	Stretch, %	Taber Stiffness, Units	Z-Direction Tensile Strength, kg./sq. cm.
						Multi-Ply Sheets						
700	None		32.3	11.1	2910	14.3	5624	506,835	47.6	2.40	34.0	5.41
			44.4	14.8	2990	18.6	7361	495,650	67.0	2.78	77.0	3.75
			53.1	17.5	3030	23.0	8508	488,733	80.3	2.86	132.2	3.66
			67.7	23.0	2950	28.0	10337	451,416	97.7	3.00	265.0	3.29
			90.6	29.8	3040	37.0	14889	499,171	132.9	3.06	568.5	3.00
600	None		32.1	10.3	3120	16.8	6210	602,894	60.0	3.01	31.4	5.84
			42.5	12.9	3290	20.6	7900	606,328	80.8	3.27	61.0	5.61
			55.0	16.1	3420	28.6	10010	612,701	106.9	3.38	126.5	5.79
			71.0	21.2	3360	36.2	12506	592,787	132.6	3.52	286.8	5.46
			98.4	28.4	3460	51.0	16758	588,972	165.2	3.78	598.0	5.43
500	None		32.2	9.5	3390	19.1	6759	718,552	67.8	3.09	27.8	7.28
			42.4	12.2	3460	22.8	8883	722,912	92.8	3.26	60.8	6.82
			50.9	14.3	3560	28.4	9964	694,685	109.4	3.42	98.8	6.93
			71.1	19.6	3620	39.0	13524	686,052	145.2	3.70	260.5	6.78
			89.3	24.6	3630	50.0	17332	703,829	188.9	3.48	499.5	6.58
400	None		42.0	11.8	3560	22.1	8997	772,280	96.1	3.38	57.2	7.50
300	None		42.7	11.8	3630	23.0	9333	801,133	101.1	3.42	58.8	7.86
600	Guar	0.25	43.4	12.6	3460	22.7	8279	656,703	90.9	3.56	62.8	6.60
		0.75	43.5	12.6	3440	23.2	8226	649,334	91.3	3.56	64.8	6.74
		1.25	43.8	12.7	3450	22.9	8512	665,520	94.9	3.60	64.7	7.02
	PEI[a]	0.25	45.1	13.3	3390	23.8	8567	641,748	95.8	3.54	71.7	6.79
		0.75	45.5	13.2	3450	25.8	8874	666,646	109.1	3.67	76.0	10.37
		1.25	44.7	13.2	3370	24.5	8731	656,116	104.7	3.75	69.0	10.42
						Single-Ply Sheets						
600	None		32.5	9.8	3300	18.7	6004	612,286	58.8	3.07	25.1	7.78
			44.5	13.2	3360	22.6	8104	610,364	77.2	2.88	65.5	7.29
			51.5	15.1	3410	27.1	9165	604,935	86.5	2.82	98.5	7.35
			69.5	20.0	3480	37.5	11649	584,341	106.8	2.76	232.2	7.20
			81.8	23.7	3450	44.4	13742	588,951	121.6	2.75	381.5	7.12

[a] Polyethyleneimine

[b] Basis weight/thickness , lb./in.(1000 sq. ft.)

TABLE II

EFFECT OF GUAR AND POLYETHYLENEIMINE ON STRENGTH AND STIFFNESS PROPERTIES OF HANDSHEETS

Per Cent Additive	Basis Weight, lb./M sq. ft.	Modified Ring Compression			Extensional Stiffness, Et			Modulus of Elasticity, E			Taber Stiffness			Z-Direction Tensile		
		lb./in.	Factor[a]	Diff., %	lb./in.	Factor[a]	Diff., %	lb./in.^{2}	Factor[a]	Diff., %	Units	Factor[a]	Diff., %	kg./cm.^{2}	Factor[a]	Diff., %
								Guar								
0	42.5	20.6	0.485	--	7900	186	--	606,328	14,270	--	61.0	1.435	--	5.61	0.132	--
0.25	43.4	22.7	0.523	+ 7.8	8279	191	+ 2.7	656,703	15,130	+ 6.0	62.8	1.447	+ 0.8	6.60	0.152	+ 15.1
0.75	43.5	23.2	0.533	+ 9.9	8226	189	+ 1.6	649,334	14,930	+ 4.6	64.8	1.490	+ 3.8	6.74	0.155	+ 17.4
1.25	43.8	22.9	0.523	+ 7.6	8512	194	+ 4.3	665,520	15,190	+ 6.4	64.7	1.477	+ 2.9	7.02	0.160	+ 21.2
								Polyethyleneimine								
0	42.5	20.6	0.485	--	7900	186	--	606,328	14,270	--	61.0	1.435	--	5.61	0.132	--
0.25	45.1	23.8	0.528	+ 8.9	8567	190	+ 2.2	641,748	14,230	- 0.3	71.7	1.590	+ 10.8	6.79	0.151	+ 14.4
0.75	45.5	25.8	0.567	+ 16.9	8874	195	+ 4.8	666,646	14,650	+ 2.7	76.0	1.670	+ 16.4	10.37	0.228	+ 72.7
1.25	44.7	24.5	0.548	+ 13.0	8731	195	+ 4.8	656,116	14,680	+ 2.9	69.0	1.544	+ 7.6	10.42	0.233	+ 76.5

[a] Factor = mechanical property/basis weight

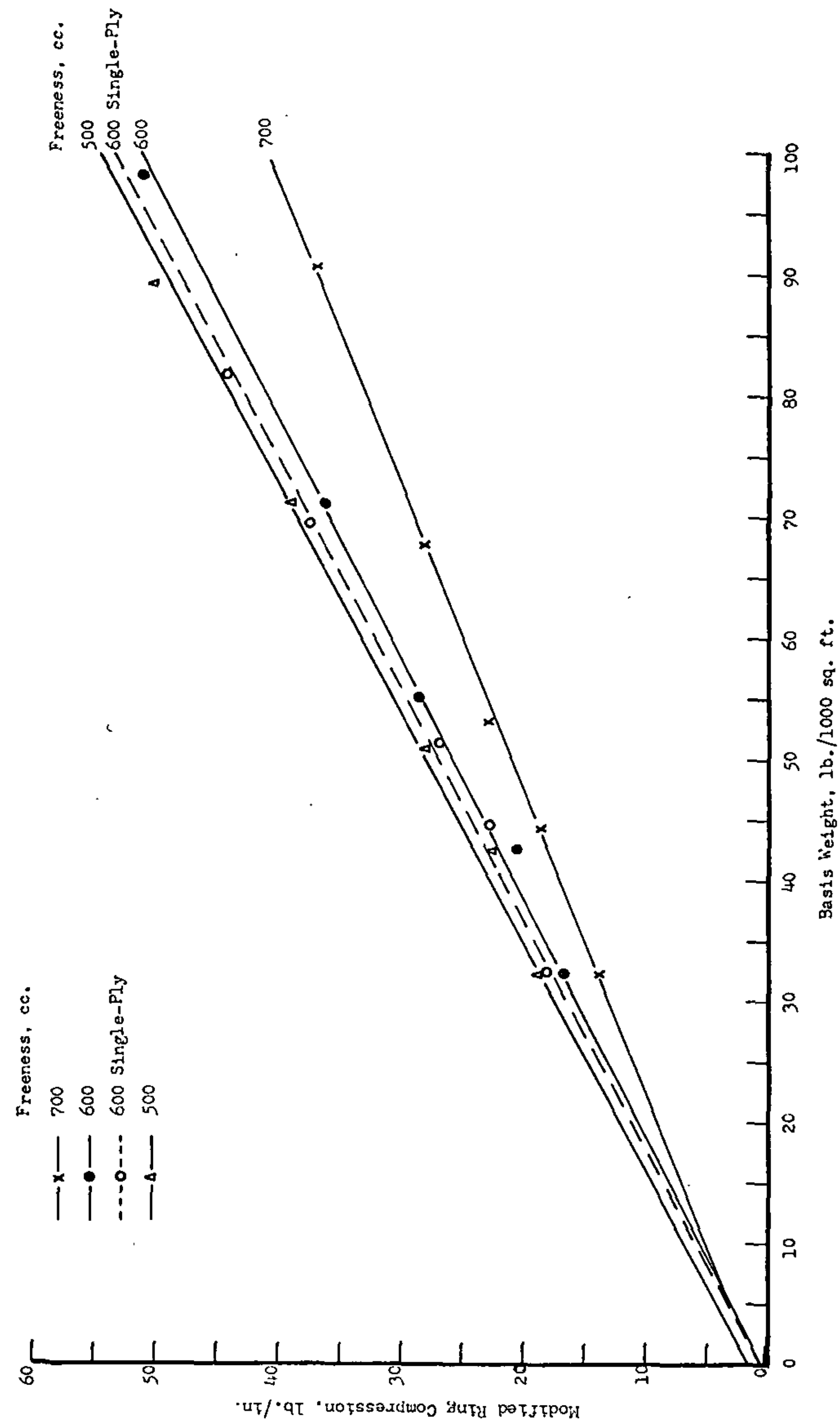

Figure 1. Relationship Between Modified Ring Compression and Basis Weight.

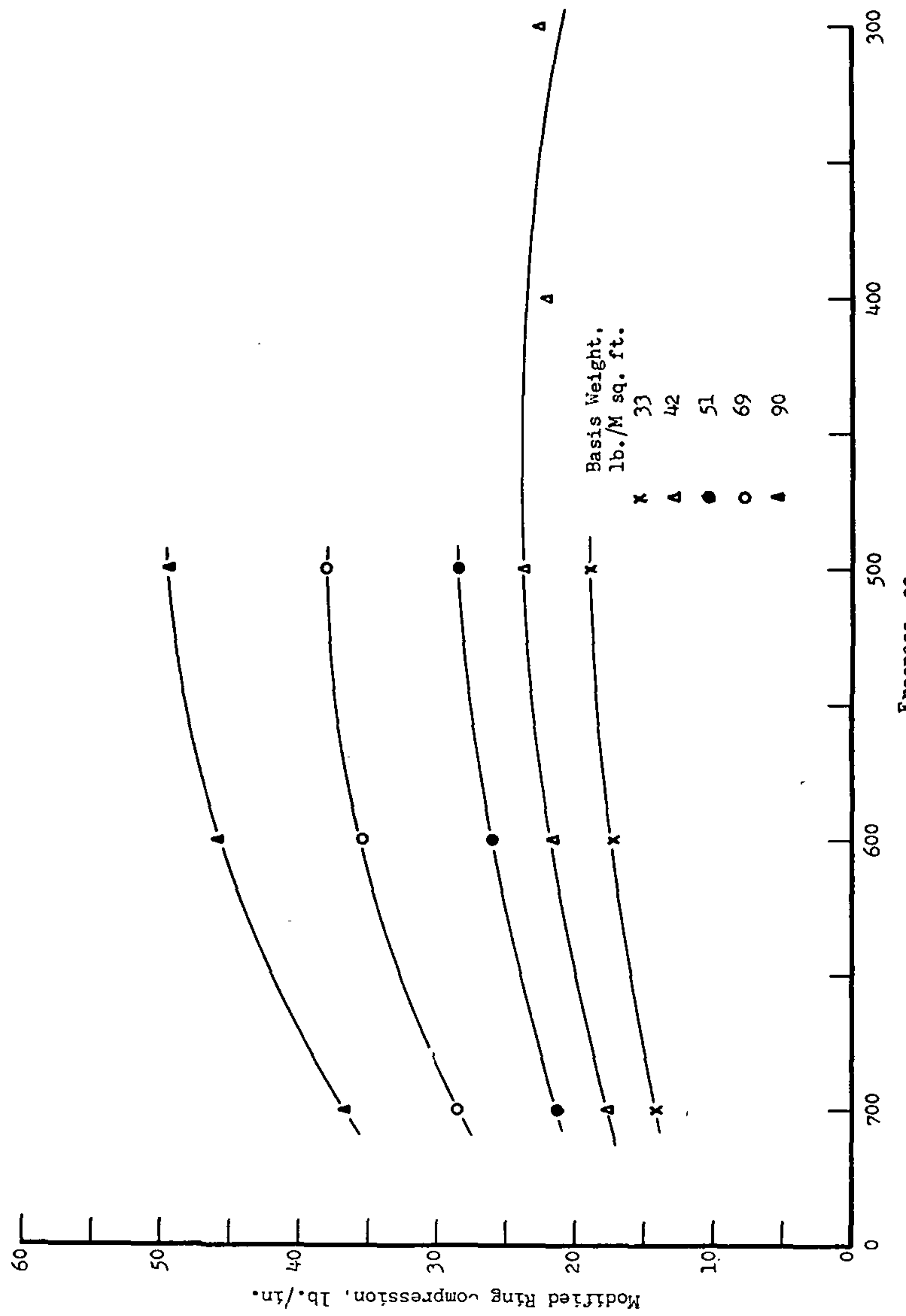

Figure 2. Relationship Between Modified Ring Compression and Degree of Refining.

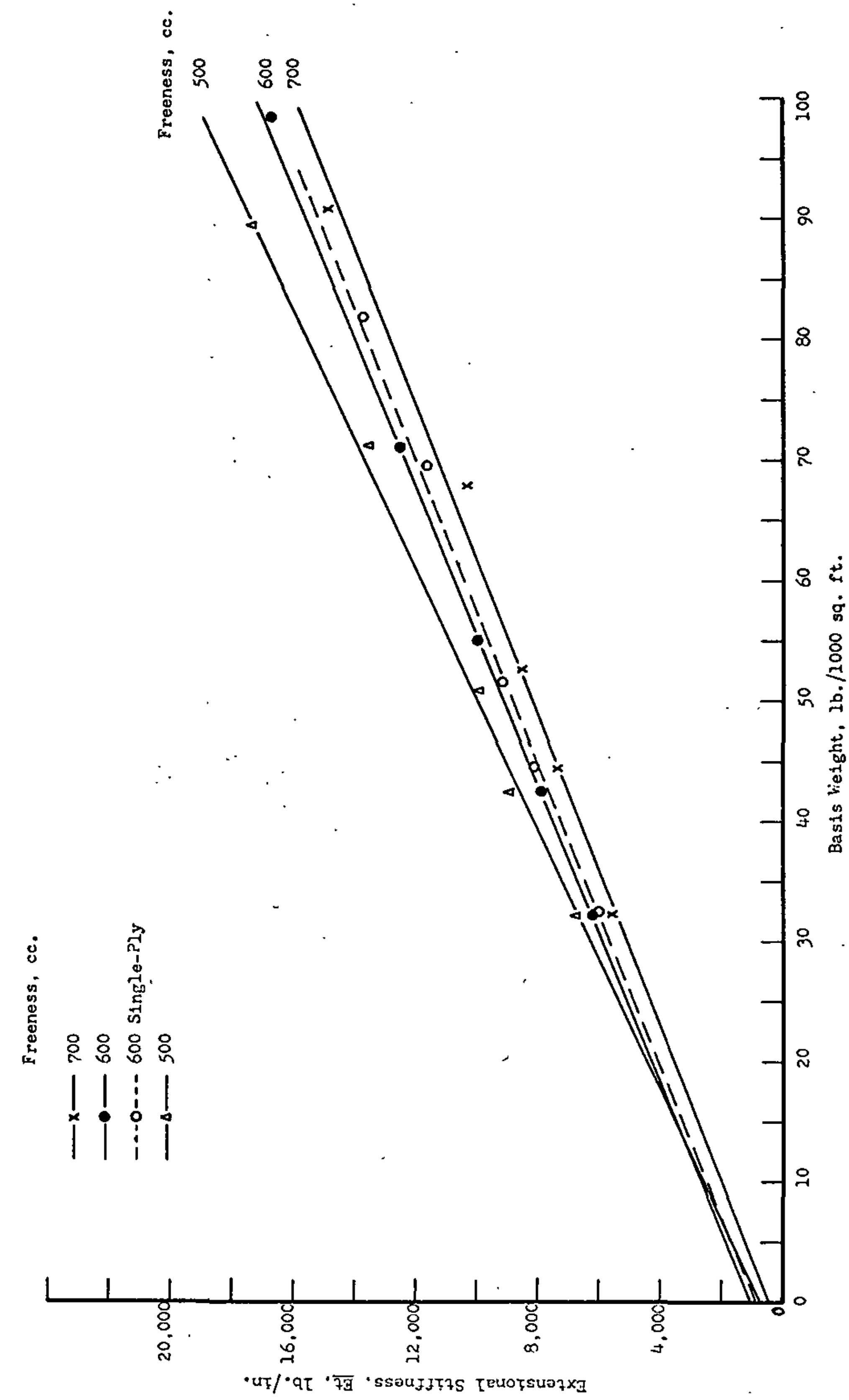

Figure 3. Relationship Between Extensional Stiffness and Basis Weight.

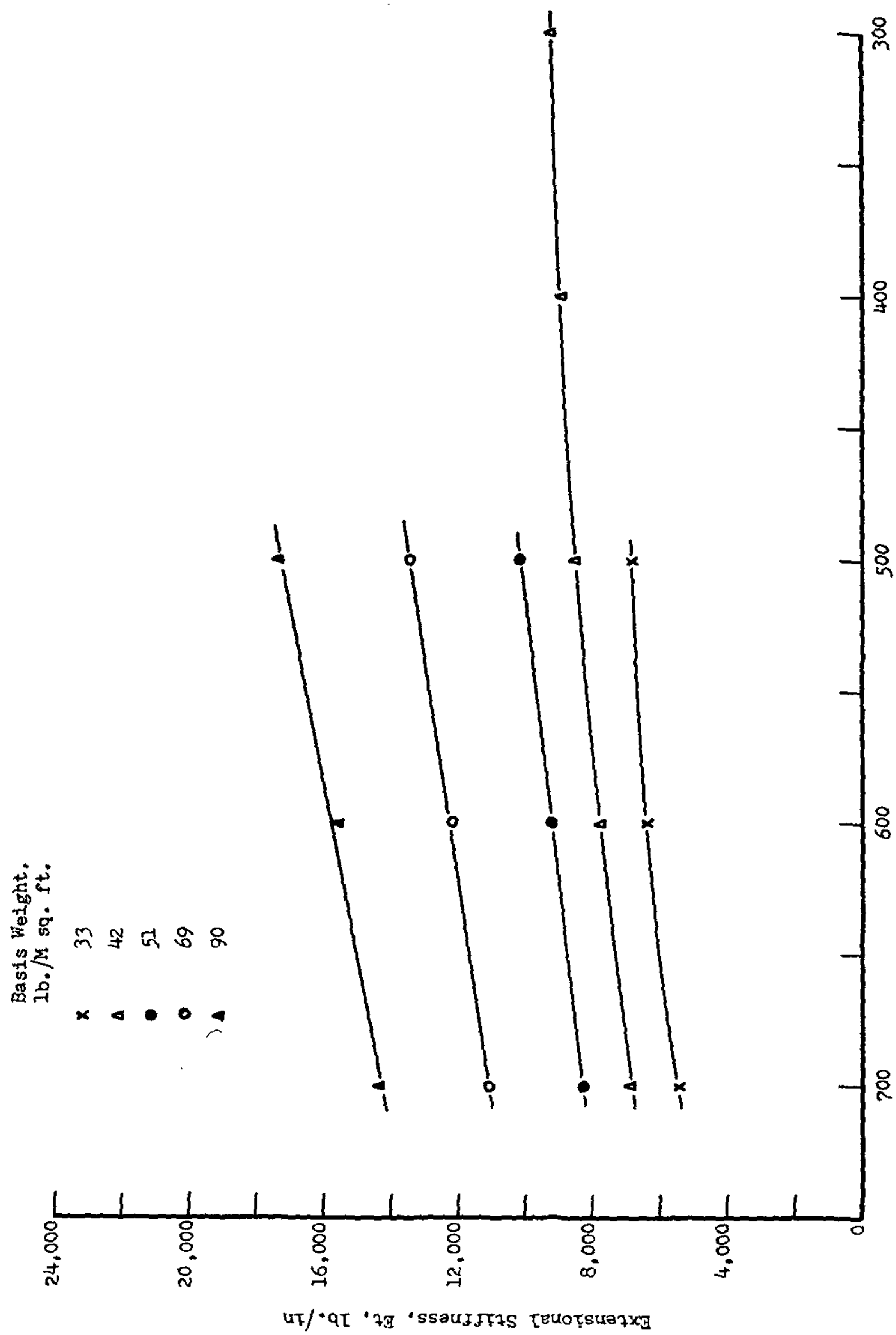

Figure 4. Relationship Between Extensional Stiffness and Degree of Refining.

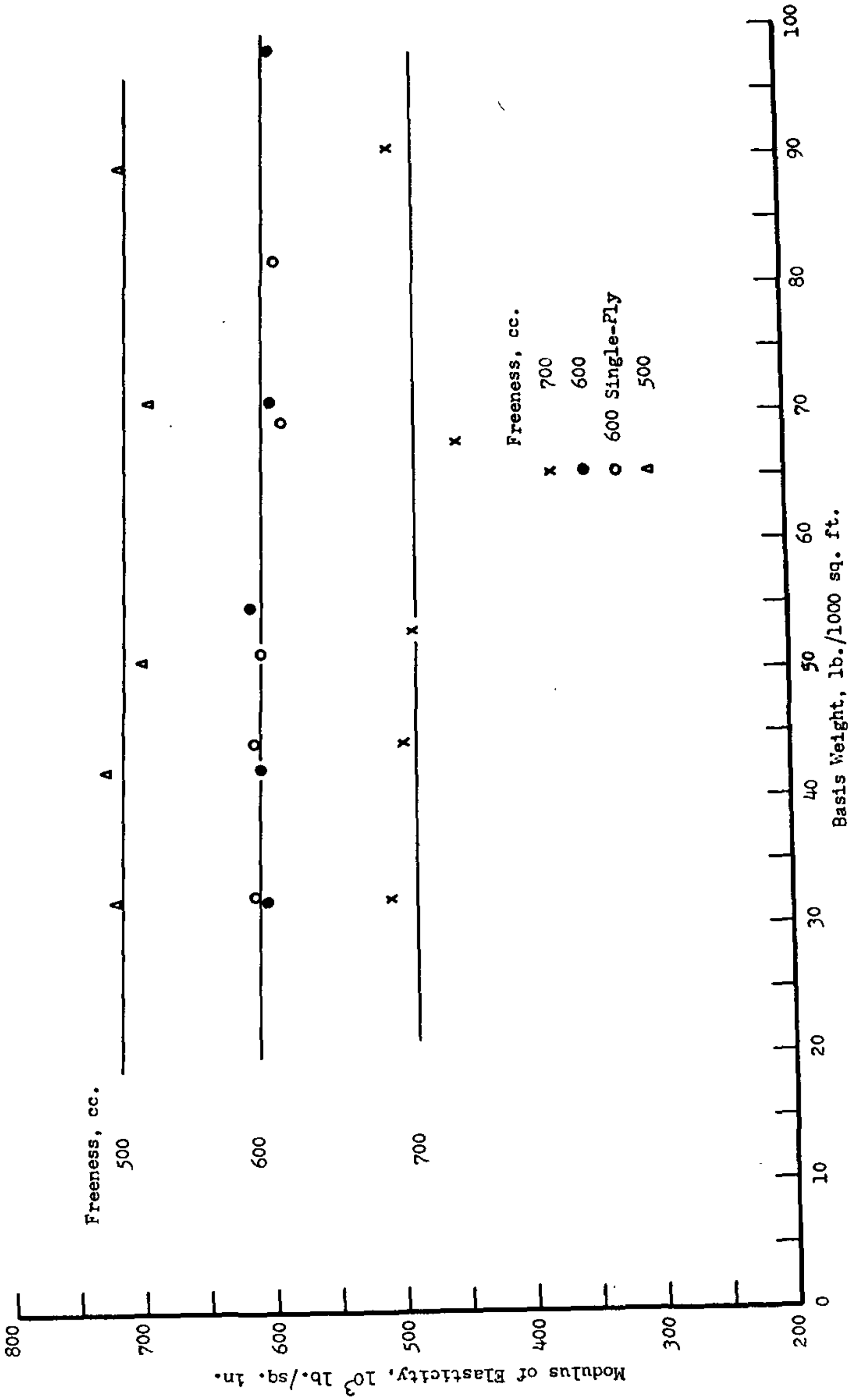

Figure 5. Relationship Between Tension Modulus of Elasticity and Basis Weight.

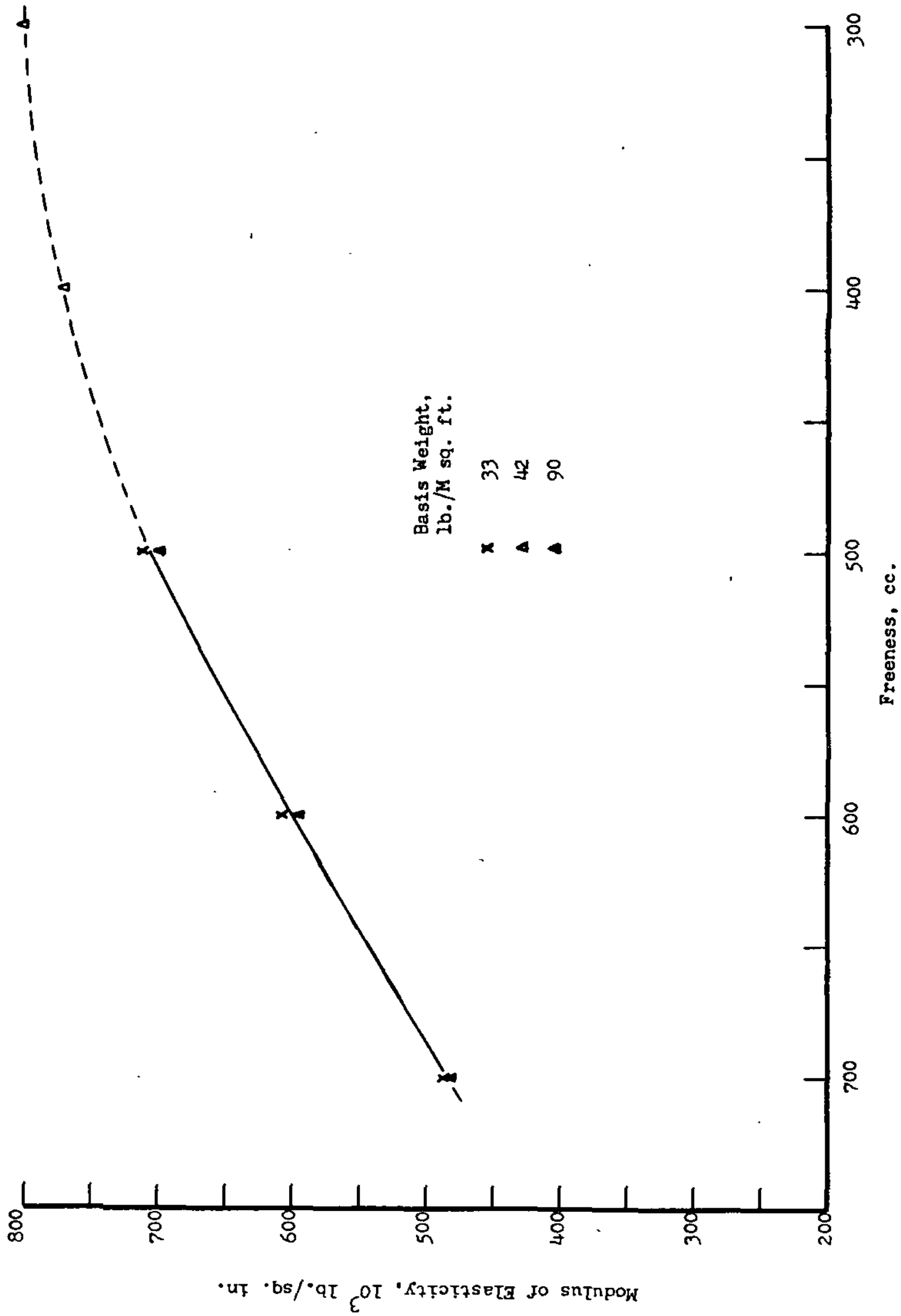

Figure 6. Relationship Between Tension Modulus of Elasticity and Degree of Refining.

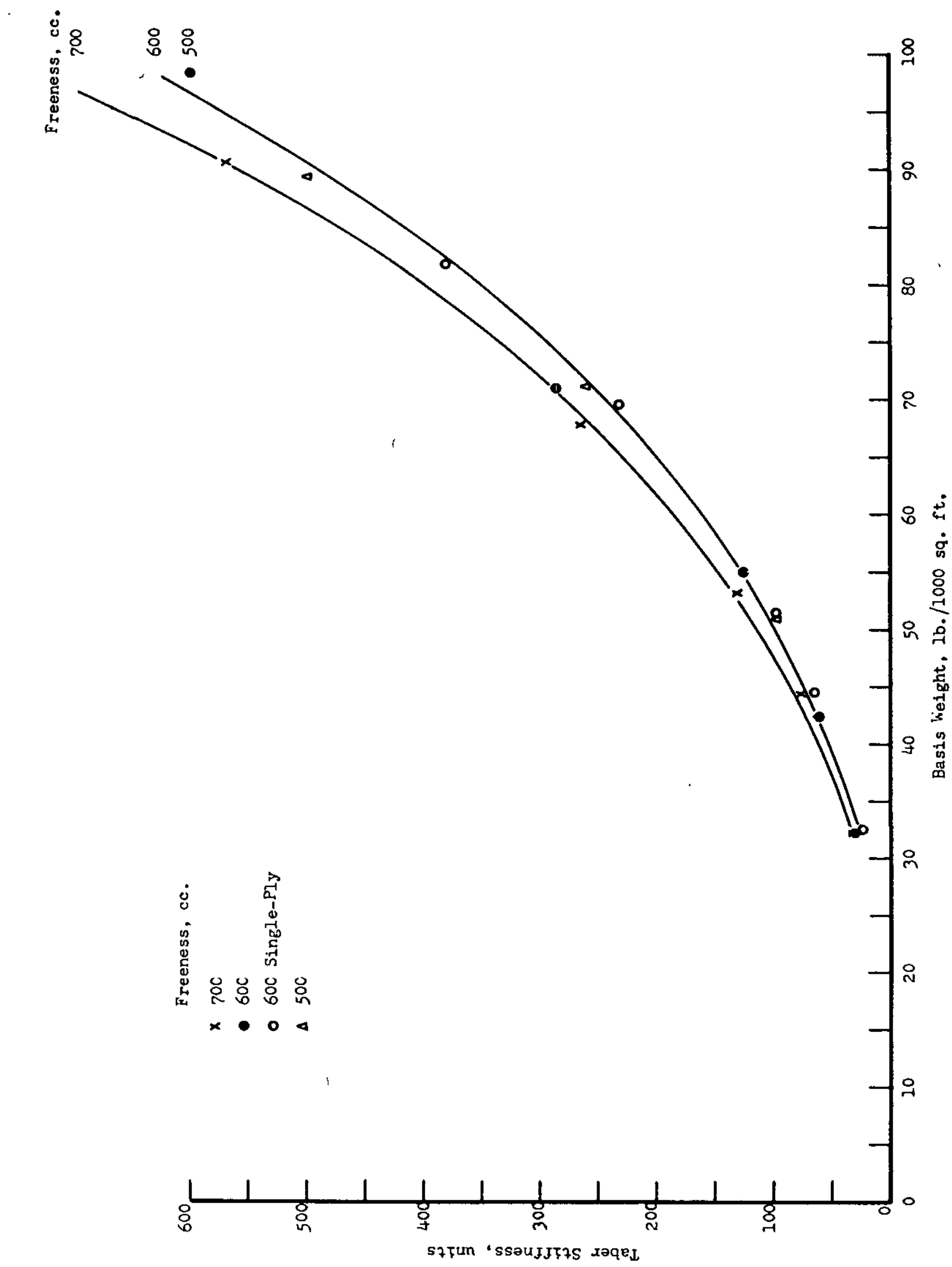

Figure 7. Relationship Between Taber Stiffness and Basis Weight.

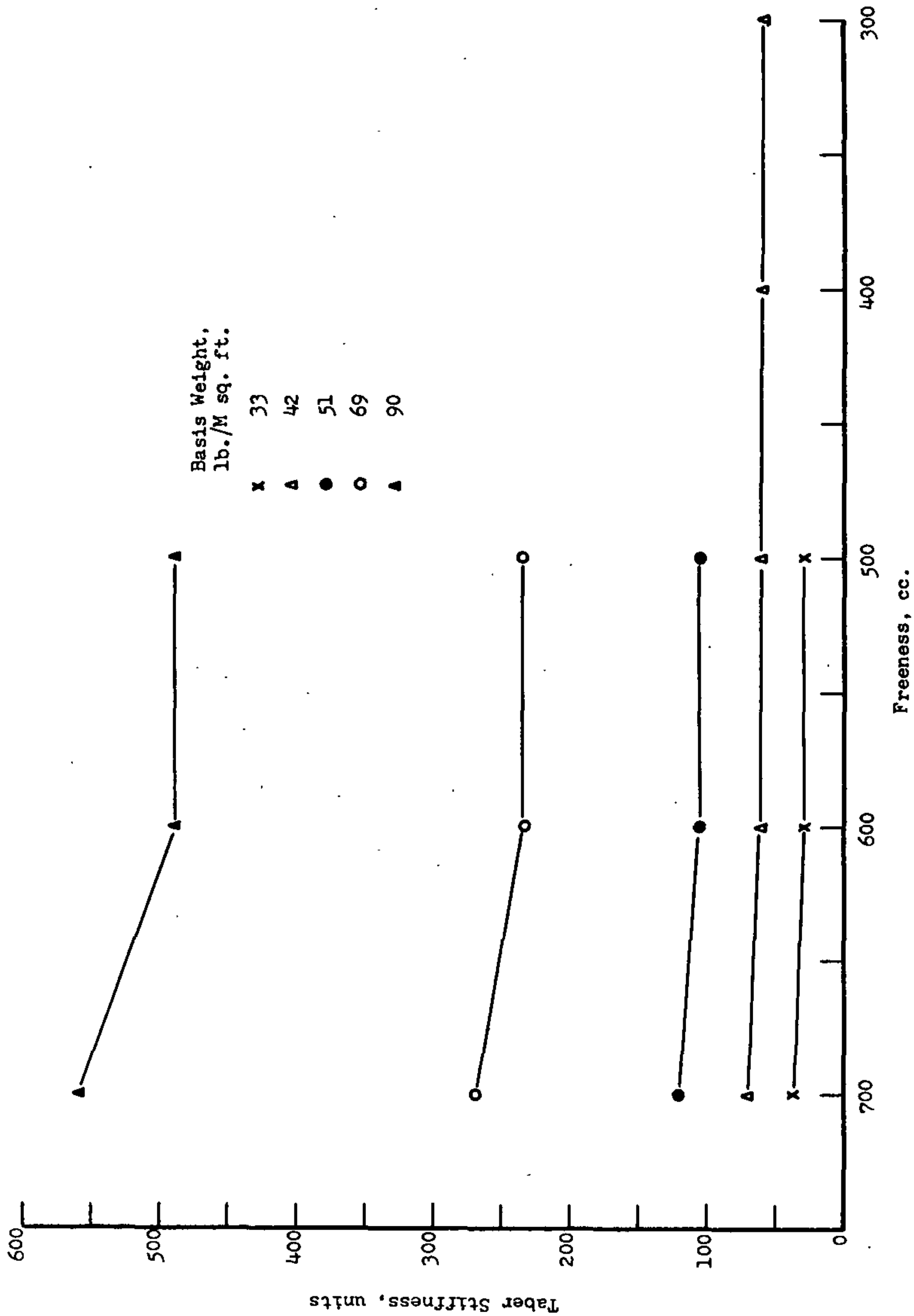

Figure 8. Relationship Between Taber Stiffness and Degree of Refining.

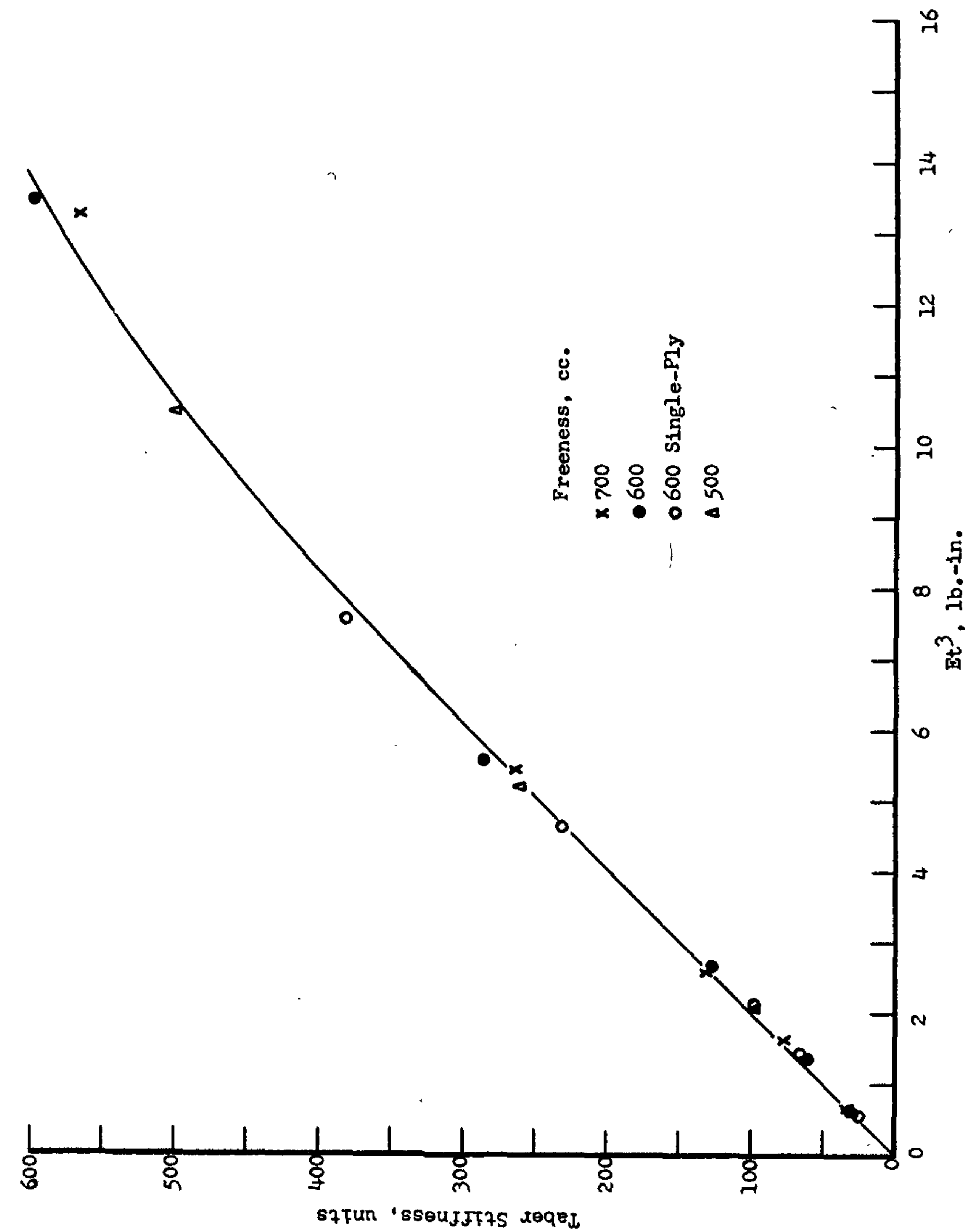

Figure 9. Relationship Between Taber Stiffness, Modulus of Elasticity, and Caliper.

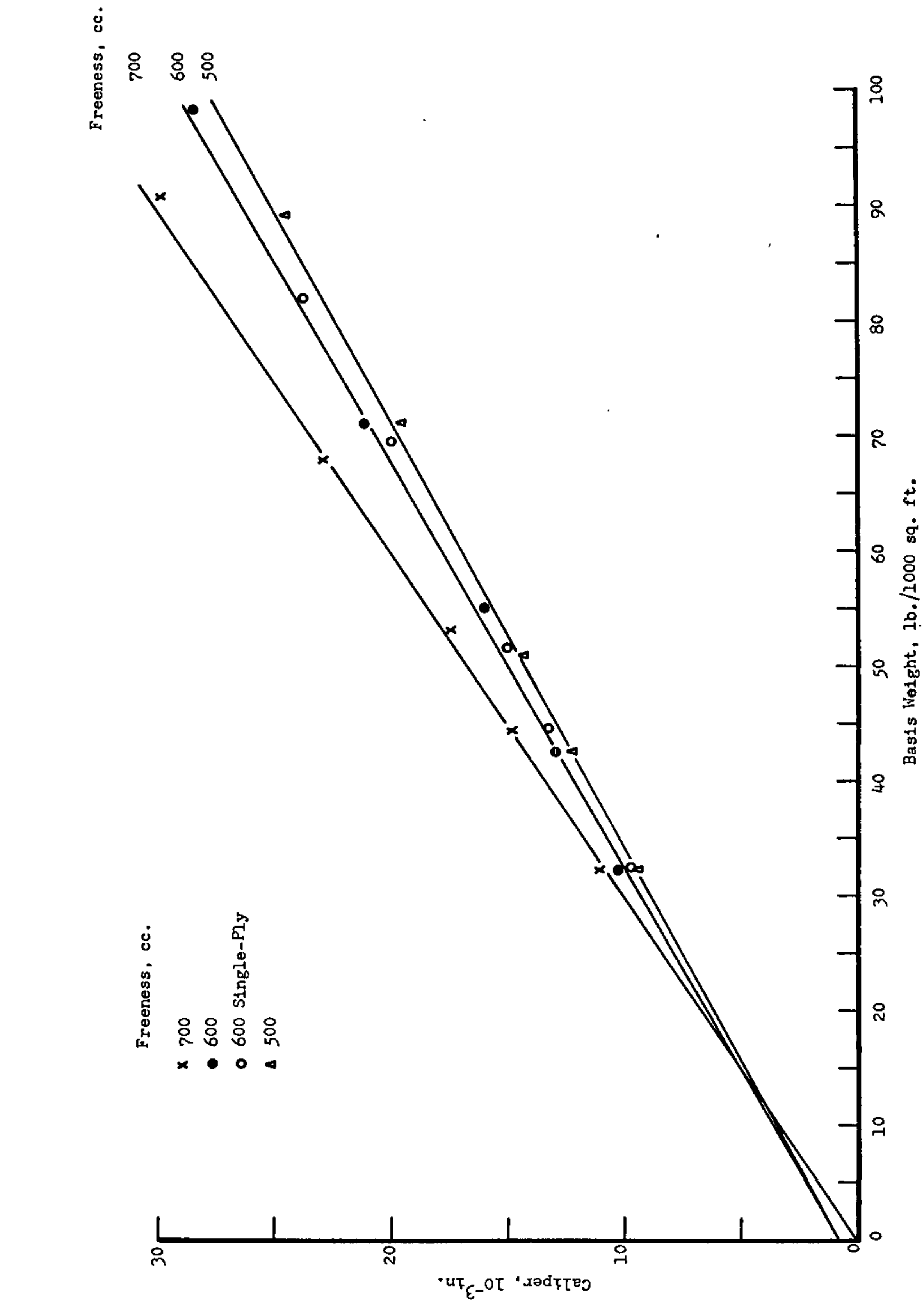

Figure 10. Relationship Between Caliper and Basis Weight.

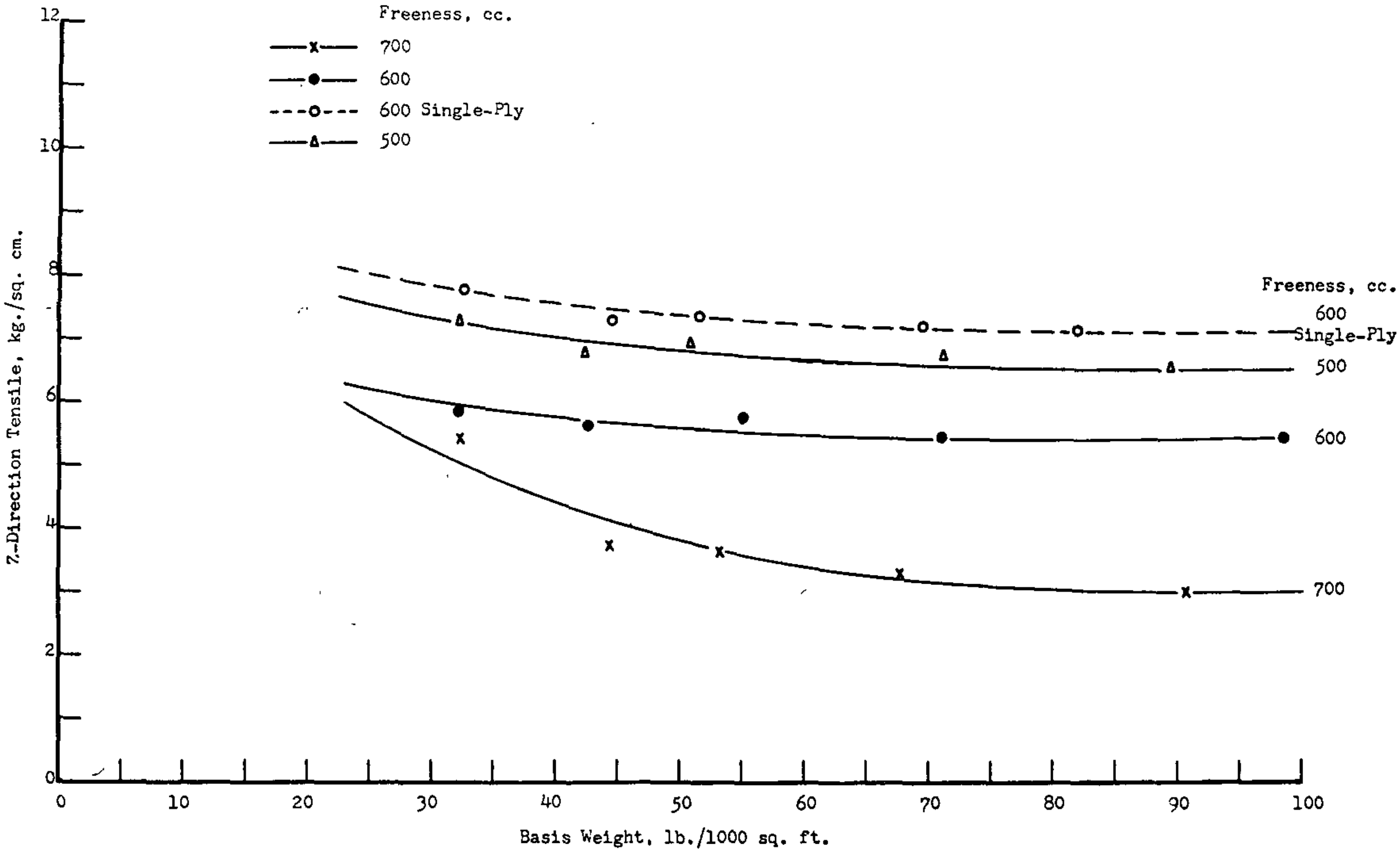

Figure 11. Relationship Between Z-Direction Tensile Strength and Basis Weight.

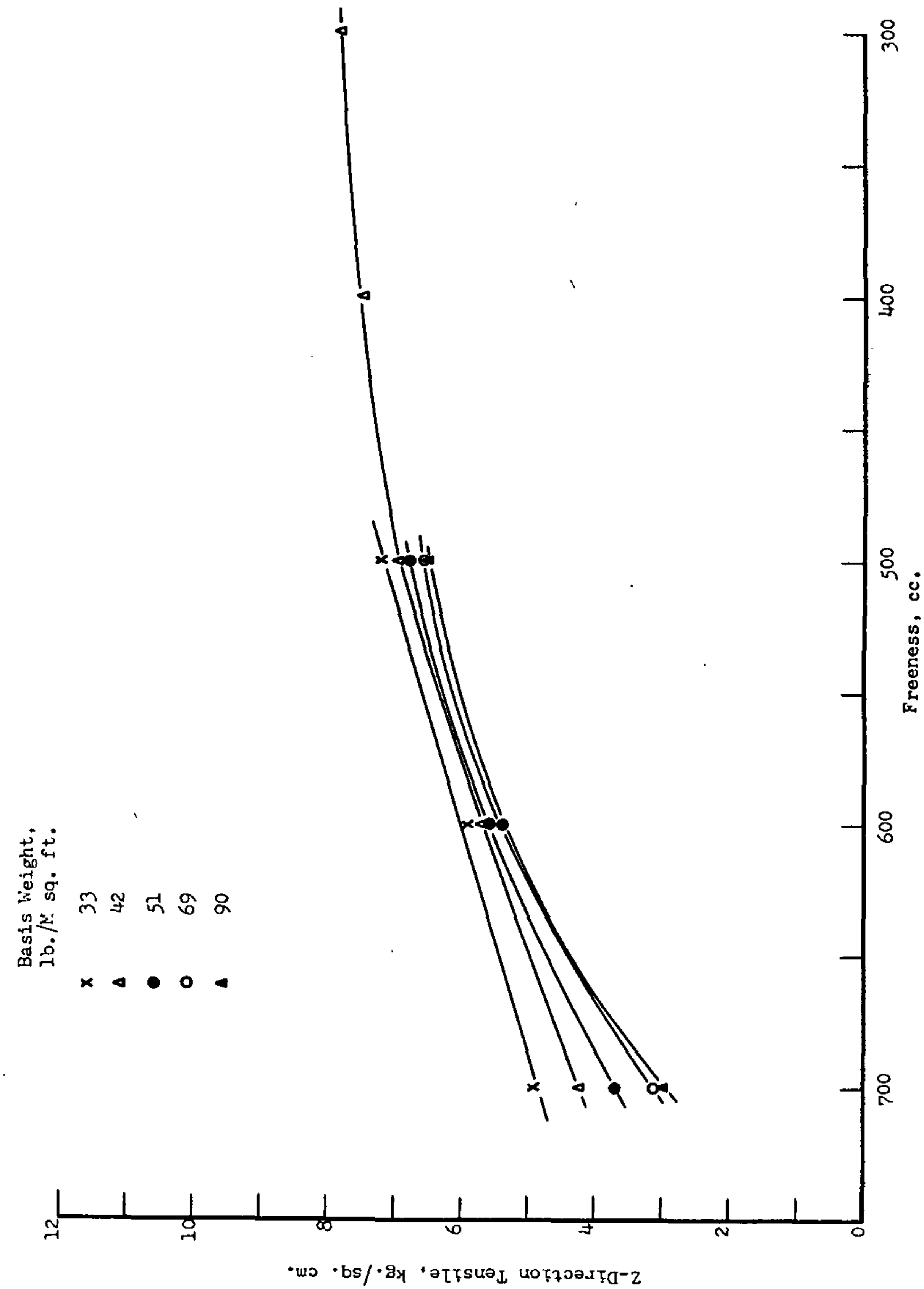

Figure 12. Relationship Between Z-Direction Tensile Strength and Degree of Refining.

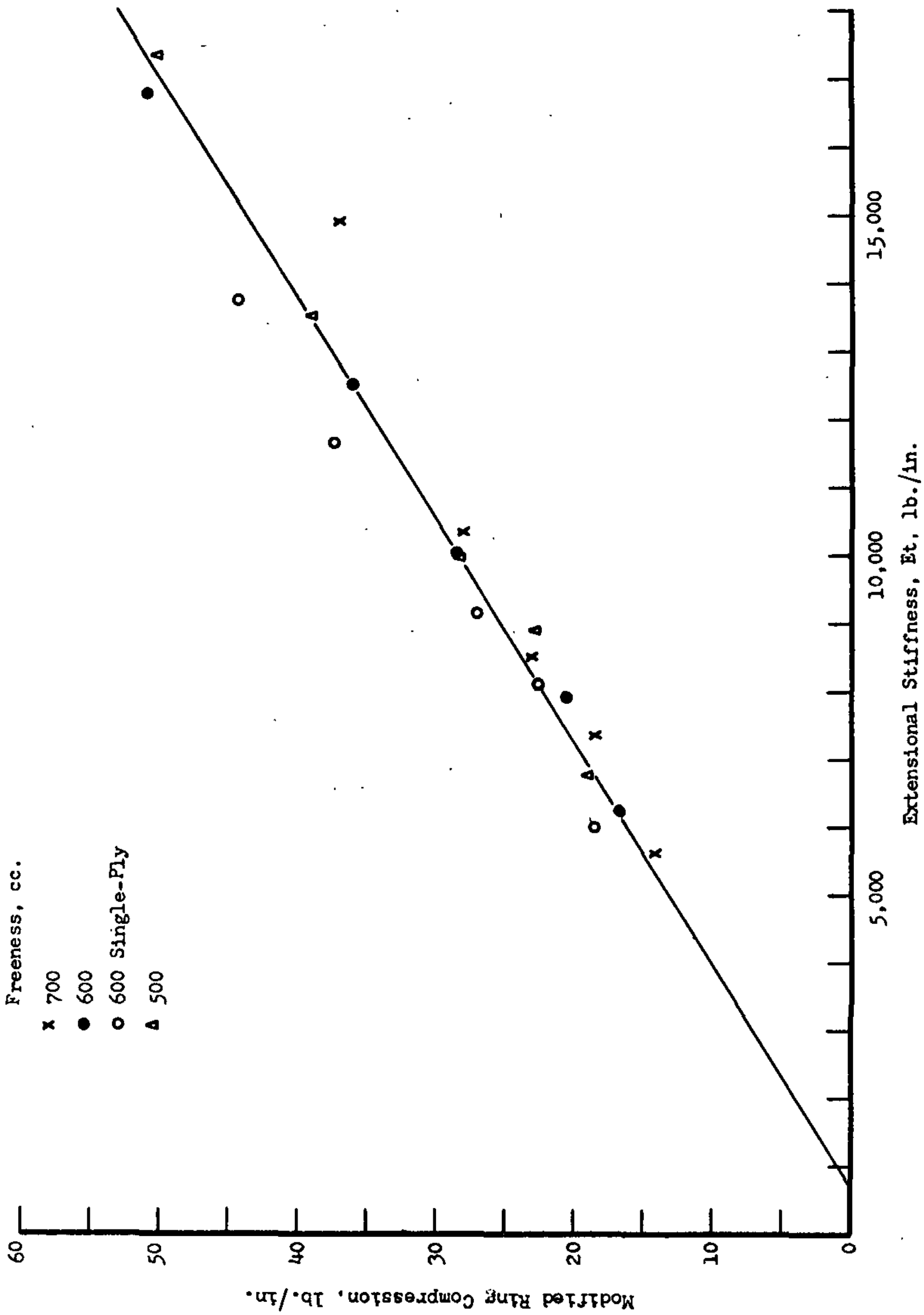

Figure 13. Relationship Between Modified Ring Compression and Extensional Stiffness.

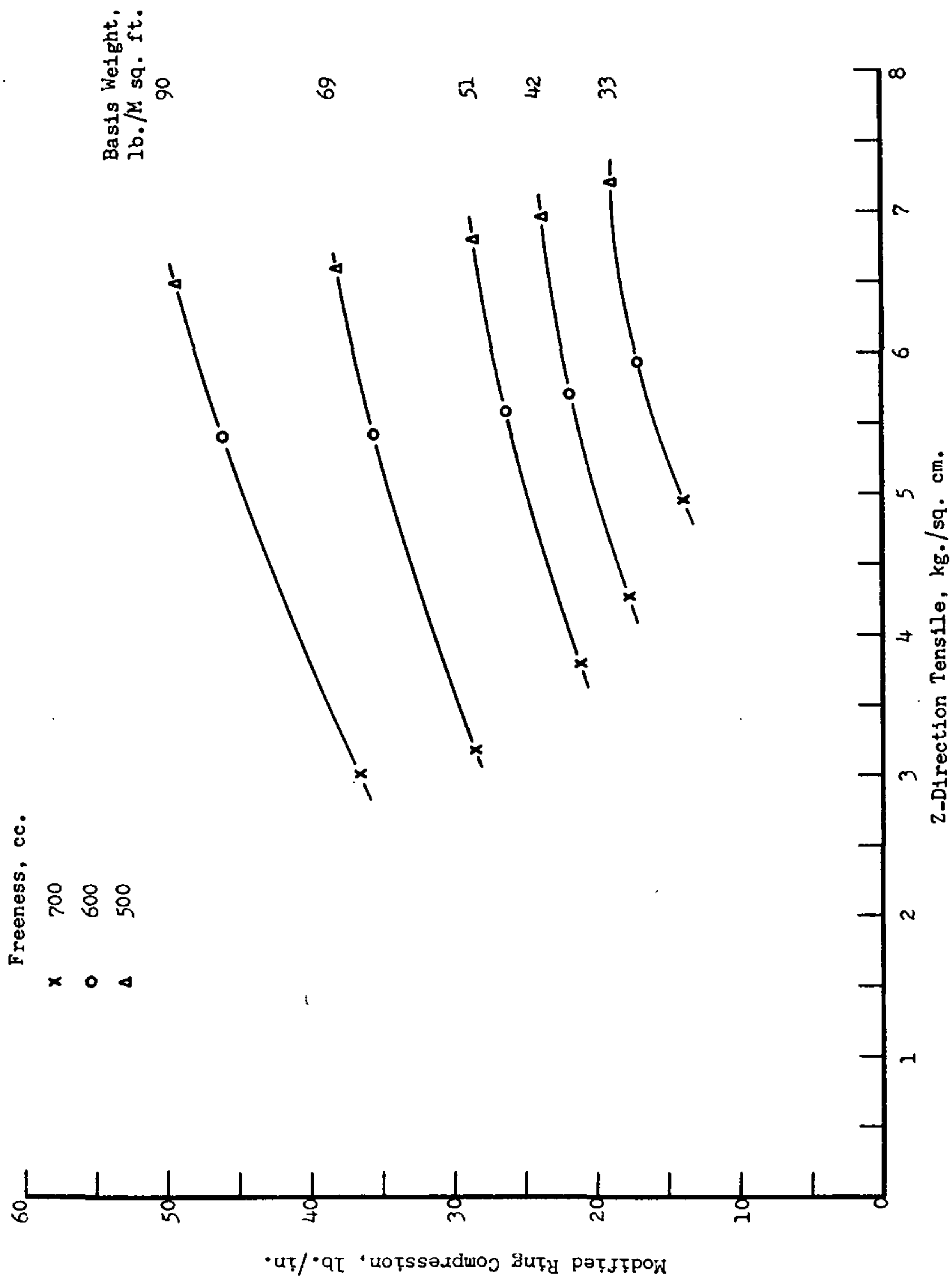

Figure 14. Relationship Between Modified Ring Compression and Z-Direction Tensile Strength.

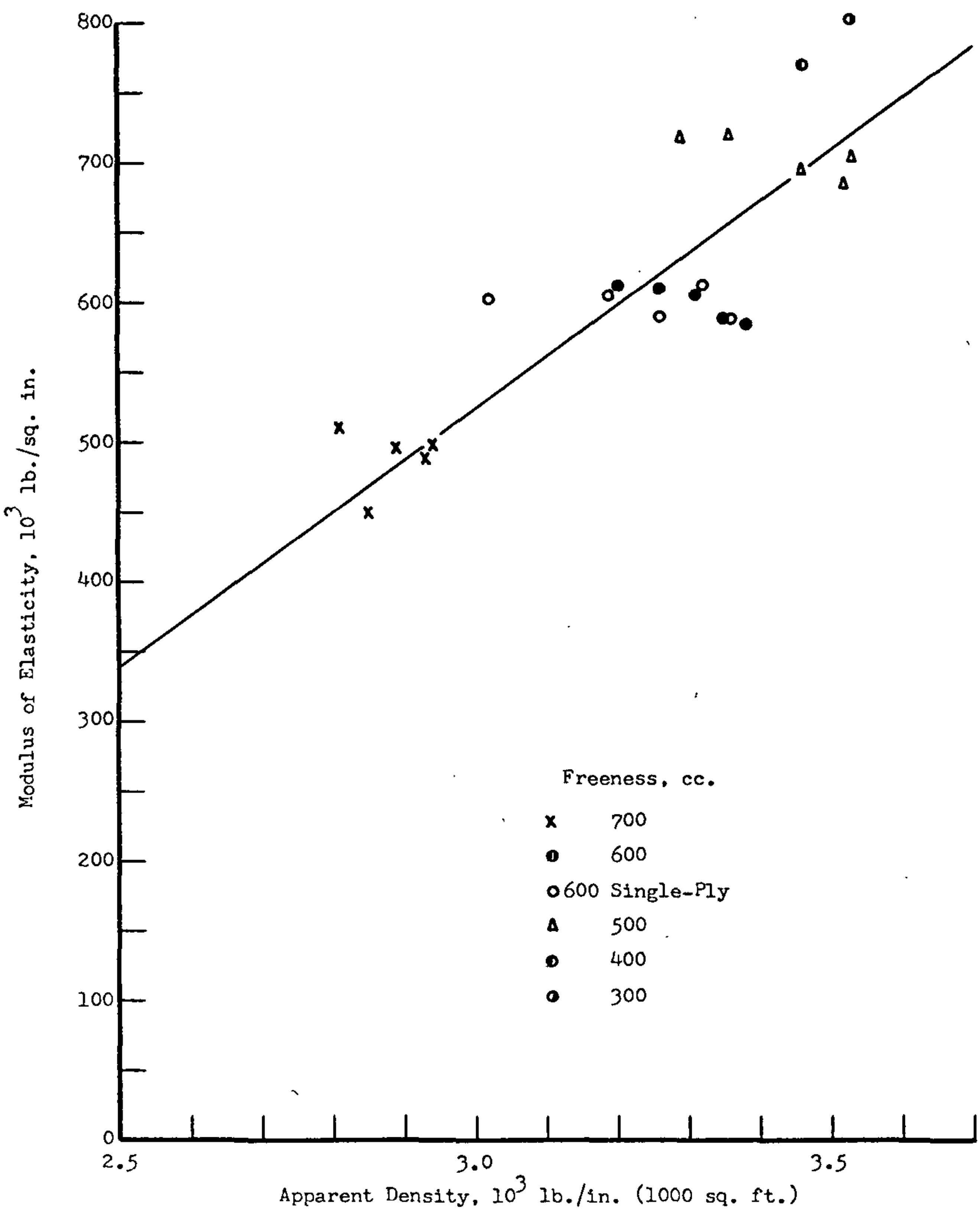

Figure 15. Relationship Between Modulus of Elasticity and Apparent Density.